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Decoding the Neurocognitive Consequences: A Comprehensive Analysis of Smoking and Alcohol Consumption on Cognitive Function Across the Lifespan

Rahel Amanda Konoralma[1*], Andreas Wilson Setiawan[2], Tyas Anggraini[3], Cynthia Arsita[4], Abidatul Hikmah[5], Hawila Maretha Krisopras[6], Alfiena Nisa Belladiena[7]

[1,2] Department of Public Health, Undergraduate Medical Program, Universitas Dian Nuswantoro
[3] Department of Molecular Biology, Universitas Dian Nuswantoro
[4] Department of Biochemistry, Undergraduate Medical Program, Universitas Dian Nuswantoro
[5,6] Medical Student, Universitas Dian Nuswantoro
[7] Faculty of Health Science, Universitas Dian Nuswantoro

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Abstract

The smoking rate continues to rise yearly, with significant increases observed among men across children, adolescents, and adults. Alcohol consumption caused 2.6 million deaths in 2019, with 2 million cases among men and 0.6 million among women. This study aimed to evaluate the influence of smoking status and alcohol consumption on cognitive function. Cognitive impairments (difficulties in thinking and understanding) are increasing health concerns, particularly in developing countries. This research was an analytic observational design with a cross-sectional approach, utilizing secondary data from 3,000 samples covering various health and lifestyle factors. The synthetic dataset mimics real-world conditions, offering a controlled environment to examine associations and minimize confounding biases—statistical analysis to assess the relationship and differences in cognitive function based on smoking status and alcohol consumption. The results showed a significant correlation between smoking habits and cognitive function, with non-smokers exhibiting better cognitive performance compared to active and former smokers. Alcohol consumption did not demonstrate significant differences in cognitive function, suggesting that factors such as consumption patterns and quantity may have a more substantial impact. Public health campaigns should leverage these insights to promote smoking cessation and address broader lifestyle factors influencing cognitive function.

Correspondence Address:
Department of Public Health, Undergraduate Medical Program, Universitas Dian Nuswantoro, Indonesia.
E-mail:
rahel.amanda@dsn.dinus.ac.id

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Introduction

Cognitive function impairments can encompass difficulties in thinking, an inability to understand proverbs, recognizing similarities, difficulty performing calculations, and difficulty grasping concepts. (Antara et al., n.d.-a). The World Health Organization (WHO) reported in 2024 that smoking causes over 8 million deaths annually worldwide, with more than 80% of tobacco users residing in low- and middle-income countries. (World Health Organization, 2023). In Indonesia, the prevalence of smokers aged 15 years and above was 30.08% of the total population in 2015, with little change over eight years, reducing to 28.62% in 2023 (Wolff, n.d.).

Several factors contribute to cognitive function deterioration, including age, gender, tobacco smoking, alcohol use, high blood pressure, diabetes mellitus, above-normal BMI, and stroke. (Antara et al., n.d.-b, 2018). Regarding gender, cognitive function tends to be better in women than men, likely due to smoking habits. Active smokers are more prone to experiencing cognitive decline compared to passive smokers. (Antara et al., 2018). While nicotine in cigarettes can provide short-term positive effects on cognitive function, long-term exposure to cigarette smoke significantly increases the risk of cognitive impairments. Smoking also reduces antioxidant levels in the body, which are essential for combating free radicals. (Baron, n.d.; Wolf et al., 2004). Moderate alcohol consumption has been shown to lower mortality rates from coronary heart disease (CHD). However, the correlation between moderate alcohol consumption and cognitive impairment remains unclear. (National Library of Medicine, n.d.).

In Indonesia, the smoking rate continues to rise yearly among men and women, with significant increases observed among men across children, adolescents, and adults. (Wolff, n.d.). Furthermore, globally, alcohol consumption caused 2.6 million deaths in 2019, with 2 million cases among men and 0.6 million among women. (World Health Organization, 2024). In Indonesia, with a population of 241 million, the prevalence of alcohol-related disorders is 0.8%, while alcohol dependency occurs in 0.7% of both men and women. (Suhardi, n.d.).

Research has identified a correlation between smoking and cognitive decline. However, evidence regarding alcohol consumption as a risk factor for cognitive decline is inconsistent. There may be a non-linear relationship between alcohol consumption and mental outcomes. For instance, a meta-analysis found a lower risk of dementia among moderate alcohol consumers (e.g., up to 14 units per week for women and 21 units per week for men) compared to non-drinkers, but this did not apply to heavy drinkers. (Hagger-Johnson et al., 2013; Kalengkongan et al., n.d.). Smoking and excessive alcohol consumption often co-occur, and their combined impact on cognition may be more significant than their individual effects. To date, few studies have examined the combined effects of smoking and alcohol consumption on cognitive decline. (Hagger-Johnson et al., 2013). Two early cross-sectional studies in community-dwelling adults in the U.S. (aged 60-84 years) produced mixed results: one found no significant combined effect. At the same time, the other reported a 6% lower overall cognitive function among those who smoked and consumed large amounts of alcohol compared to different groups. Evidence on the combined effects of smoking and alcohol on the risk of cognitive impairments, cognitive decline, or Alzheimer's disease in older populations remains inconsistent. (Hagger-Johnson et al., 2013).

Given this background, the authors conducted a study using secondary data on smoking status and alcohol consumption habits related to cognitive dysfunction to determine whether there is a correlation between smoking and drinking alcohol with cognitive function impairments. (Hagger-Johnson et al., 2013). This study uses secondary data from a synthetic dataset chosen for its ability to replicate real-world health and lifestyle variables while minimizing potential biases. Using secondary data offers the advantage of cost-efficiency and scalability, particularly in contexts where collecting primary data may introduce biases or ethical constraints. By leveraging this dataset, the study aims to evaluate the independent and mixed impacts of smoking and alcohol consumption on cognitive function, providing insights relevant to public health strategies.

Methods

This research utilized an analytic observational study design with a cross-sectional approach, leveraging secondary data obtained from the following source: Human Age Prediction Synthetic Dataset on Kaggle (https://www.kaggle.com/datasets/abdullah0a/human-age-prediction-synthetic-dataset) that was conducted from November 12 to November 14, 2024. The dataset was explicitly created to simulate real-world health and lifestyle conditions, offering 3,000 rows and 24 features, including smoking status, alcohol consumption habits, and cognitive function indicators. While synthetic, the dataset was validated against

real-world trends, ensuring its reliability in reflecting typical patterns observed in population-based studies.

The synthetic dataset was constructed using advanced modeling techniques to replicate demographic and health-related distributions found in empirical datasets. Validation processes confirmed that the dataset aligns with expected associations between variables such as age, smoking, alcohol use, and health outcomes, enhancing its utility for analytical studies.

Before analysis, the dataset underwent a thorough cleaning process to ensure accuracy and consistency. Missing values were imputed using median imputation for continuous variables and mode imputation for categorical variables. Outliers were detected using interquartile range (IQR) methods and removed to maintain the integrity of the data.

To minimize confounding effects, key demographic and lifestyle variables, including age, gender, BMI, and pre-existing health conditions (e.g., hypertension, diabetes), were controlled during the analysis. Smoking status was categorized into three groups: current smokers, former smokers, and never smokers. Alcohol consumption was divided into frequent, occasional, and non-consumers. Cognitive function was assessed as a continuous variable based on a composite score derived from relevant features in the dataset.

The Kolmogorov-Smirnov test was used to assess data normality. Differences in cognitive function across smoking and alcohol consumption groups were analyzed using one-way ANOVA, followed by Tukey's post hoc test for pairwise comparisons. The homogeneity of variance was tested using Levene's test. Statistical significance was set at $p < 0.05$.

Results

Smoking Status and Cognitive Function

The analysis of the effect of smoking status on cognitive function revealed significant statistical differences among current smokers, former smokers, and those who never smoked. The results are summarized in Tables and visualized in the following graph (Figure 1).

Table 1. Relationship between Smoking Status and Cognitive Function

Smoking Status	Cognitive Function		p-value
	Mean ± SD	Median (min-max)	
Current	62.78 ± 11.37	62.67 (35 – 95)	0.200*
Former	63.38 ± 11.74	63.22 (30 – 106)	0.200*
Never	65.28 ± 11.95	65.87 (31 – 101)	0.200*

*Data distribution is Normal (p > 0,05), tested using the Kolmogorov-Smirnov test

Using the Kolmogorov-Smirnov test, cognitive function data across smoking status groups showed a normal distribution. Therefore, further analysis was conducted using a one-way ANOVA test.

Table 2. Cognitive Function Differences Based on Smoking Status (One-Way ANOVA)

Smoking Status	Mean ± SD	p-value	Levene
Current	62.78 ± 11.37	<0.001*	0,332**
Former	63.38 ± 11.74		
Never	65.28 ± 11.95		

* Significant (p < 0,05); ** Homogenous varience (Levene > 0,05)

The one-way ANOVA analysis revealed a significant difference in cognitive function based on smoking status, with a p-value of <0.001 indicating statistical significance ($p < 0.05$). The Levene test value of 0.332 suggests homogeneity of variance, indicating that the observed differences in cognitive function among smoking status groups are consistent.

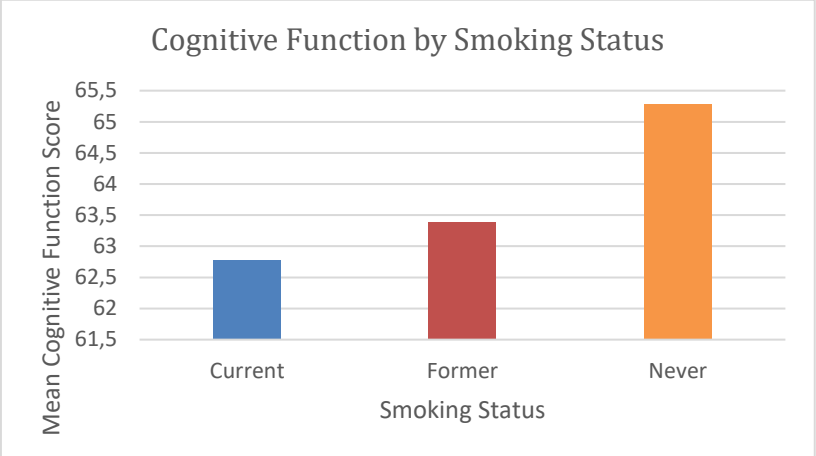

Figure 1. Cognitive Function by Smoking Status

Post hoc analysis using the Tukey HSD test revealed significant differences between current smokers and non-smokers ($p < 0.001$), as well as between former smokers and non-smokers ($p < 0.001$). However, no significant difference was found between current smokers and former smokers ($p = 0.507$). These results indicate that individuals who never smoked exhibit significantly better cognitive function compared to those who currently or formerly smoked.

Table 3. Post Hoc Analysis for Cognitive Function Differences Among Smoking Status Groups

Smoking Status		p-value
I	II	
Current	Former	0.507
	Never	<0.001*
Former	Never	<0.001*

*Significant ($p < 0,05$)

Alcohol Consumption and Cognitive Function

The analysis of the impact of alcohol consumption on cognitive function involved 3,000 participants divided into groups and tested using ANOVA and descriptive statistics. The results are summarized in Tables 4, 5, and Figure 2.

Table 4. Relationship between Alcohol Consumption and Cognitive Function

Alcohol Consumption	Cognitive function		p-value
	Mean ± SD	Median (min-max)	
Frequent	64.57 ± 11.72	64.47 (31 – 101)	0.200*
Occasional	63.43 ± 11.88	63.43 (33 – 102)	0.200*
None	63.82 ± 11.66	64.12 (30 – 106)	0.116*

* Data distribution is Normal ($p > 0,05$), tested using the Kolmogorov-Smirnov test.

Cognitive function data across alcohol consumption groups showed a normal distribution using the Kolmogorov-Smirnov test. A one-way ANOVA test was used to further analyze the data.

Table 5. Cognitive Function Differences Based on Alcohol Consumption (One-way ANOVA)

Alcohol Consumption	Mean ± SD	p-value	Levene
Frequent	64.57 ± 11.72	0.127	0.868**
Occasional	63.43 ± 11.88		
None	63.82 ± 11.66		

*Non-Significant ($p < 0,05$); ** Homogenous variance (levene > 0,05)

The one-way ANOVA analysis showed no significant differences in cognitive function based on alcohol consumption frequency ($p = 0.127$). The Levene test value of 0.868 indicates homogeneity of variance across groups.

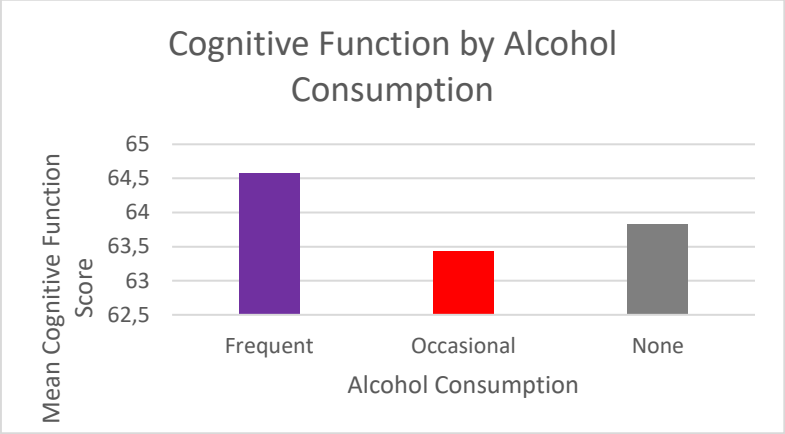

Figure 2. Cognitive Function by Alcohol Consumption

Smoking status displayed a significant association with cognitive function, likely due to the long-term effects of nicotine and tobacco exposure on oxidative stress and neurodegeneration. On the other hand, the lack of significant findings for alcohol consumption may indicate that other factors, such as consumption patterns, duration of use, or interactions with underlying health conditions, play a more prominent role.

Discussion

The results of this study demonstrate a significant association between smoking status and cognitive function, whereas no such relationship was observed for alcohol consumption. These findings offer important insights into the differential impact of these behaviors on cognitive health.

Impact of Smoking on Cognitive Function

The significant association between smoking and cognitive function aligns with existing literature. Long-term smoking has been shown to accelerate neurodegeneration through increased oxidative stress and reduced antioxidant levels. (Baron, n.d.; Wolf et al., 2004). The current study supports these findings, revealing that individuals who never smoked have better cognitive performance than current and former smokers. The absence of significant differences between current and former smokers suggests that the detrimental effects of smoking may persist even after cessation, emphasizing the need for early intervention and prevention strategies.

Non-Significant Association Between Alcohol Consumption and Cognitive Function

The lack of a significant relationship between alcohol consumption and cognitive function may be attributed to several factors. First, the dataset categorized alcohol consumption based on frequency without accounting for quantity or patterns, such as binge drinking or moderate daily consumption, which are critical in determining cognitive outcomes. (National Library of Medicine, n.d.)Second, the study's cross-sectional design limits its ability to capture the long-term effects of alcohol consumption, which might require longitudinal data to uncover more nuanced relationships.

Furthermore, prior studies have shown mixed results, with some suggesting the protective effects of moderate alcohol intake on cognitive function and others highlighting its risks, particularly with heavy consumption. (Hagger-Johnson et al., 2013; Kalengkongan et al., n.d.). The current findings suggest that frequency alone may not sufficiently capture the complexity of alcohol's effects on cognition, necessitating further investigation into dose-dependent and contextual factors.

Combined Effects of Smoking and Alcohol Consumption

While this study did not directly test the combined effects of smoking and alcohol consumption, previous research indicates that these behaviors often co-occur and may have additive or synergistic impacts on cognitive health. (Hagger-Johnson et al., 2013). Future studies should explore this interaction to understand better the compounded risks associated with these lifestyle factors.

Alignment with Existing Literature

The findings on smoking are consistent with studies emphasizing its long-term negative impact on brain health. Conversely, the non-significant result for alcohol consumption challenges the notion of its direct impact on cognition, highlighting the need for more comprehensive research on this topic.

Conclusion

Based on the analysis of the effects of smoking and alcohol consumption on cognitive function, the following conclusions were drawn: Smoking status significantly influences cognitive function. Individuals who never smoked tend to have better cognitive performance compared to active and former smokers. These findings suggest that smoking behavior increases the risk of cognitive decline, emphasizing the importance of smoking prevention as a measure to maintain cognitive health. Meanwhile, Alcohol consumption frequency did not show a significant relationship with cognitive function. The average cognitive function across groups with varying alcohol consumption frequencies did not differ statistically. This indicates that other factors, such as consumption patterns and quantity, might substantially influence cognitive function more than frequency alone.

These findings highlight the critical role of controlling smoking habits by conducting Public Health campaigns that focus on community-based interventions targeting smoking prevention and cessation. Programs should emphasize the long-term cognitive health benefits of avoiding tobacco use. Meanwhile, the government should advocate for stricter regulations on smoking and increase public awareness campaigns to reduce smoking prevalence, particularly among vulnerable populations. Lastly, further research is needed to understand the impact of alcohol consumption on cognitive function fully. Identifying risk or protective patterns in alcohol use may help inform strategies to optimize cognitive health. These findings offer actionable insights for public health strategies aimed at mitigating cognitive decline through lifestyle modifications, particularly addressing smoking behavior.

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